

TECHNOLOGY UTILIZATION

ELECTRONIC SWITCHES  
AND  
CONTROL CIRCUITS

**CASE FILE  
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A COMPILATION



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

## Foreword

The National Aeronautics and Space Administration and the Atomic Energy Commission have established a Technology Utilization Program for the dissemination of information on technological developments which have potential utility outside the aerospace and nuclear communities. By encouraging multiple application of the results of their research and development, NASA and AEC earn for the public an increased return on the investment in aerospace research and development programs.

The innovations in this updated series of compilations dealing with electronic technology represents a carefully selected collection of items on electronic switches and control circuits. Most of the items are based on well-known circuit design concepts that have been simplified or refined to meet NASA's demanding requirement for reliability, simplicity, fail-safe characteristics, and the capability of withstanding environmental extremes. The items included in the sections dealing with signal and power switching circuits should be of interest to the technician and electronic hobbyist because of their simplicity and low cost.

Additional technical information on individual devices and techniques can be requested by circling the appropriate number on the Reader Service Card included in this compilation.

Unless otherwise stated, NASA and AEC contemplate no patent action on the technology described.

We appreciate comment by readers and welcome hearing about the relevance and utility of the information in this compilation.

Jeffrey T. Hamilton, *Director*  
*Technology Utilization Office*  
*National Aeronautics and Space Administration*

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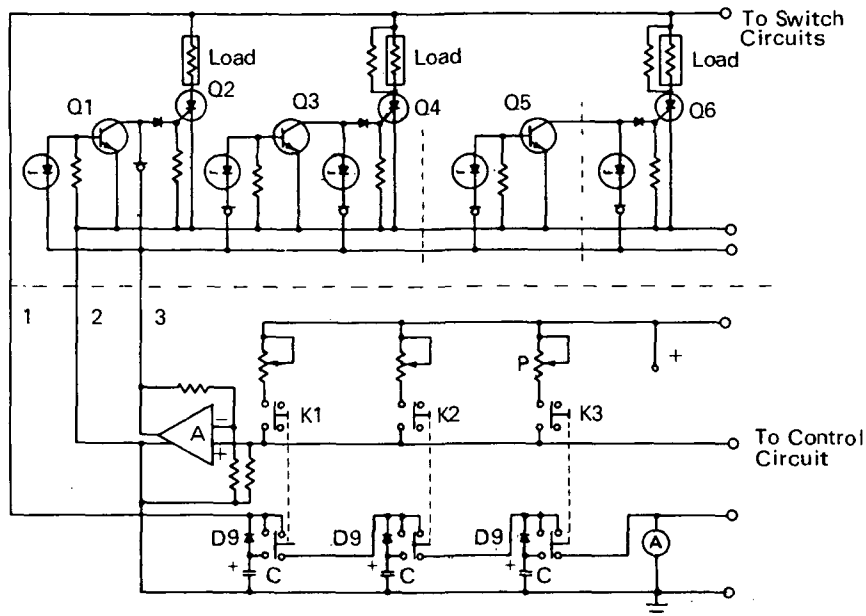
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# Section 1. Signal Switches

## SOLID-STATE REMOTE-CIRCUIT SELECTOR SWITCH

A solid-state remote control circuit uses voltage logic to switch on a desired circuit without the use of mechanical relays, frequency responsive circuits, or capacitors. Important circuit design features include: a three-conductor

the control switch applies a potential to the input of amplifier (A) when any of the control switches are depressed. The amplifier output is routed through line 3 to the SCR gate "inhibit" or "fire" circuits.



wire connection between the central control circuit and the remote switch circuits; a continuous central-control circuit indication of the remote switch circuit that is activated; and a capability of activating any remote circuit switch in any order of desired sequence.

The remote switching action is produced by silicon controlled rectifiers (Q2, Q4, and Q6) which conduct current through the loads. The SCR's are latched in the "on" state by the application of current to the gate terminal. Load current is routed via line 1 as a series connection through one section of each of the control switches K1, K2, K3, etc., and returns to circuit ground via line 2. A second section of

The multirange switch has a 10-circuit switching capacity. Larger switching capacity is limited only by the closeness of the voltage bandwidth and the voltage breakdown limitations of the constant-current diodes. The circuit can also be used in a coded remote-circuit activator where a predetermined sequence of remote switching must occur in a defined length of time to prevent false or undesired circuit activation.

Source: V. S. Peterson  
Lewis Research Center  
(LEW-10387)

*No further documentation is available.*

## REMOTELY ACTUATED BIOMEDICAL SWITCH

The implantable electronic switch shown in the figure consumes no power in the off condition and can be actuated by a single-frequency telemetry pulse.

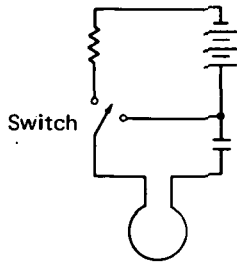


Figure 1

The actuator (see Figure 1) for the remotely-actuated biomedical switch generates an rf signal when the spring-loaded, momentary-contact switch shorts the capacitor through the inductance of the antenna. When returned to its normal position, the switch reconnects the battery and allows the capacitor charge to be established through the resistor. The operating distance of the actuator is determined by the charge stored by the capacitor. Since the values of the capacitor and the inductance of the antenna determine the resonant frequency, the operating frequency can be readily adjusted within the frequency range of the antenna tank circuit of the implanted electronic switch.

The biomedical instrument can be deenergized on command by recycling the actuator. The ferrite antenna picks up the rf pulse from the actuator which saturates amplifier switch Q1, charging capacitors C2 and C3 to the battery voltage. Since SCR1 is already in conduction, its gate circuit is inactive and, therefore, the charging current through capacitor C2 has no effect. However, the charging current through

capacitor C3 to the gate of SCR2 will initiate a current impulse through its anode-to-cathode circuit, momentarily saturating amplifier switches

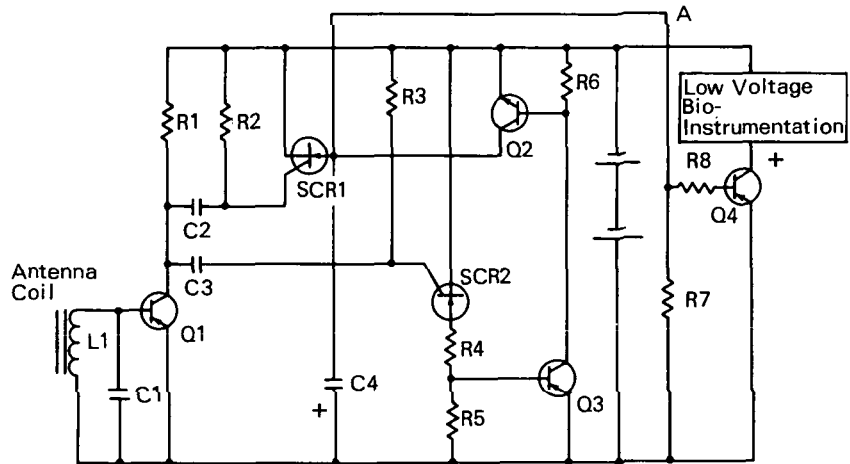


Figure 2

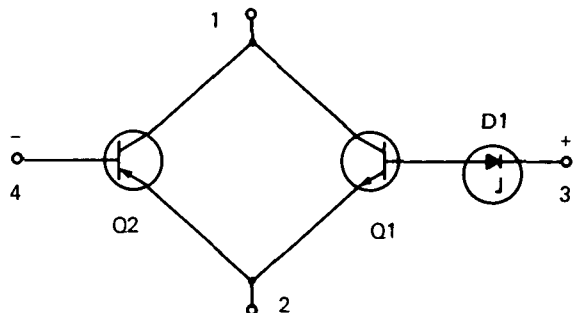
Q2 and Q3, thus short-circuiting the anode-to-cathode circuit of SCR1. As a result, SCR1 reverts to its nonconducting state because its anode current is now at a much lower value with capacitor C4 fully charged. Consequently, all active semiconductor devices revert to their off conditions, and the biomedical instrument is deactivated.

The sensitivity of the electronic switch to rf impulses from the actuator drops off as the third power of the distance. Additionally, the receiving circuit is quite insensitive, but this lack of sensitivity offers an advantage in that the system is not likely to be triggered by extraneous signals. Ideally, the actuator is used in close proximity to the implanted electronic switch; other forms of rf activation may provide actuation at long distances. Antenna inductance L1 is tuned by varying the number of turns on the ferrite cylinder core.

Source: Ames Research Center  
(ARC-10105)

Circle 1 on Reader Service Card.

### ELECTRONIC BIDIRECTIONAL VALVE CIRCUIT ELIMINATES CROSSOVER DISTORTION AND THRESHOLD EFFECT



A four-terminal network forms a bidirectional, thresholdless valve that can switch an ac signal without crossover distortion or threshold effect. The zener voltage is selected at a level sufficiently low to protect the emitter-base junctions of Q1 and Q2 from reverse voltage breakdown. Terminals 1 and 2 provide the ac signal input while terminals 3 and 4 provide the dc control voltage.

With the control-signal supply voltage reduced to zero, the electronic valve can block ac input signal voltages equal to the breakdown voltage of D1. When operated from a dc current source, the ac signal current component is alternated by an amount equal to the product of the gain and dc bias current.

The prime advantage of this network is that an isolated control signal is sufficient for circuit turn-on without requiring the isolated dc power supply to carry the ac load current.

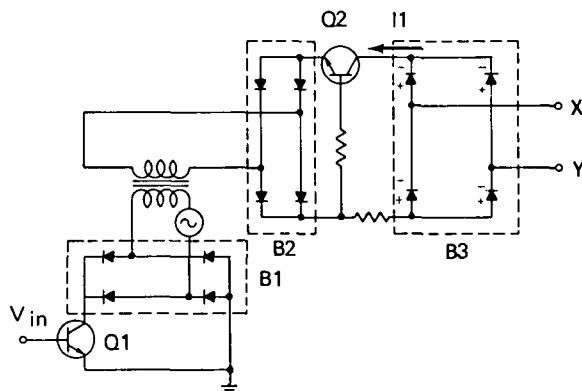
Source: A. Kernick of  
Westinghouse Electric Corp.  
under contract to  
Manned Spacecraft Center  
(MSC-00193)

Circle 2 on Reader Service Card.

### BILATERAL, ZERO-IMPEDANCE SEMICONDUCTOR SWITCH

A static semiconductor switching circuit eliminates the undesirable features of electromechanical relays—slow switching speed, contact bounce, contact pitting, and arcing—and the non-linear characteristics of conventional semiconductor switching circuits.

The “relay contacts” for this circuit are represented by terminals X and Y. The switch is closed by a positive control signal voltage which forward biases transistor Q1 and switches it to the conducting state. With Q1 on, the ac voltage is applied to the transformer primary through the diode bridge circuit B1. The secondary voltage of the transformer is full-wave rectified by diode bridge circuit B2. The output from this bridge circuit turns on transistor Q2 and provides the current to forward bias the diodes of bridge circuit B3, in the linear and low resistance region of their current-voltage characteristic curves. The final result of this current flow is to produce a net zero-voltage drop at terminals X and Y and thus a zero impedance for bilateral currents at these terminals.

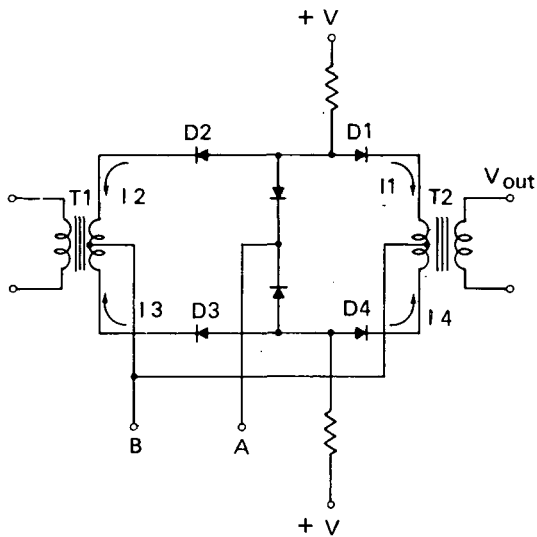


The switch is turned off by removing the control signal voltage from Q1. The bias current  $I_1$  becomes zero, and Q2 is open circuited, i.e., the switch is now opened.

Source: C. L. Doughman of  
Westinghouse Electric Corp.  
under contract to  
Lewis Research Center  
(LEW-10129)

Circle 3 on Reader Service Card.

## BALANCED RF SWITCH MINIMIZES SWITCHING TRANSIENTS



A balanced diode-transformer circuit can switch rf signals in the 120 MHz range by alternately driving a biased diode network at the rate of 1.5 kHz. The balanced circuit pro-

vides low noise switching for rf signals by suppressing transformer voltage spikes and would be useful in high frequency signal switching applications that require low noise operation.

The rf switch shown in the figure is turned on by applying a positive voltage at A and a negative voltage at B. The diodes D1, D2, D3, and D4 are turned on and as a result, the flow of current I2 balances I3, and I1 balances I4. Consequently, the voltages induced by the diode currents cancel in the transformers T1 and T2, and the voltage spikes generated by the diode currents are minimized. The switch is turned off by reversing the polarity of the voltages at A and B.

Source: J. R. Pousson of

TRW

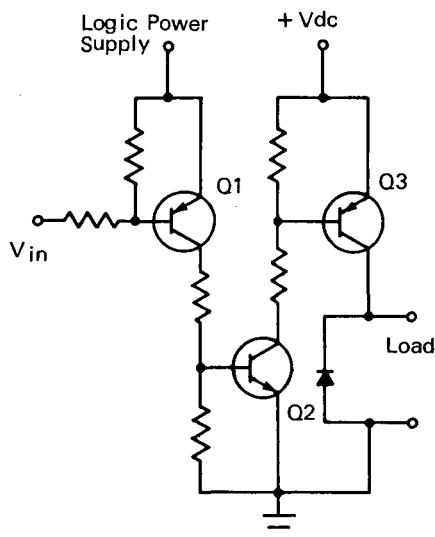
under contract to

Manned Spacecraft Center

(MSC-13241)

*Circle 4 on Reader Service Card.*

## SOLID-STATE SWITCH CONSUMES NEGLIGIBLE POWER



This solid-state switch is designed for a short period of "on" time and consumes very little power during the "off" time.

The switch is ideal for driving small loads such as lamps, relays, etc., from logic levels with

very little power consumption when the switch is "off." The "on" time is short relative to the "off" time.

The circuit consists of three transistors operated in the switching mode. Q1 is a PNP transistor with its emitter connected to the positive logic power supply. Q2 is an NPN transistor used to drive the output switch Q3 that connects the supply voltage to the load. When the input is at ground potential, Q1, Q2, and Q3 saturate and the switch is "on." When the input is open circuited or connected to the logic power supply, all the transistors are "off"; hence, when the switch is "off," very little power is consumed, only that due to leakage currents of the transistors.

Source: R. Shigemasa of

North American Rockwell Corp.

under contract to

Manned Spacecraft Center

(MSC-91041)

*No further documentation is available.*

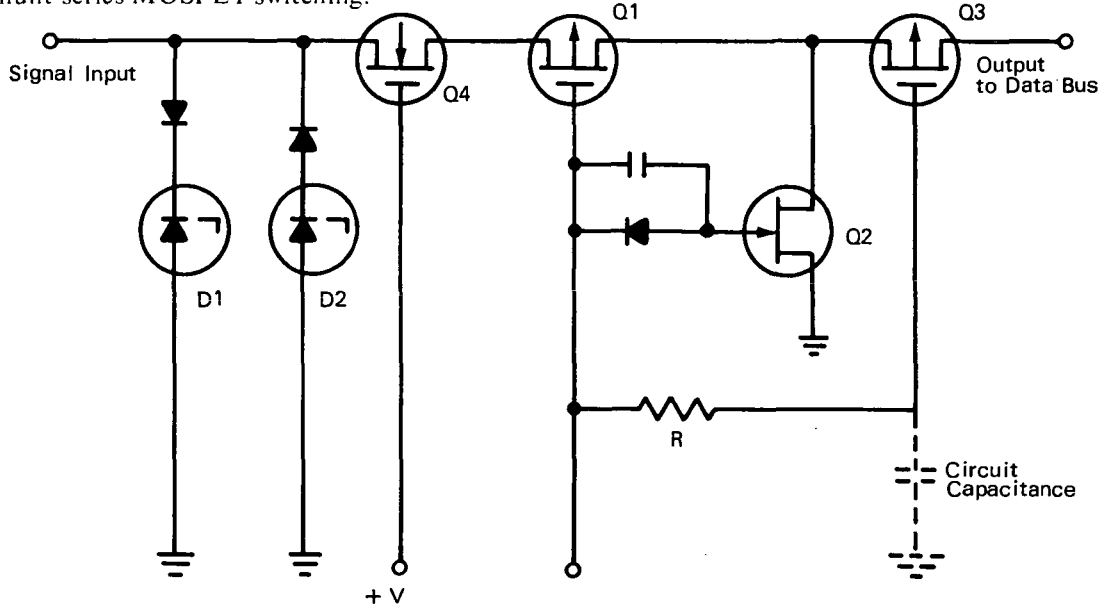




### SOLID-STATE SWITCH PROVIDES HIGH INPUT-TO-OUTPUT ISOLATION

The solid-state switch can interrupt a 50 kHz signal (10 mV to 80 V peak range) with input-to-output isolation of 80 db. The high input-output isolation is achieved through the use of series and shunt-series MOSFET switching.

load reactance to discharge through Q3 and Q2 to ground. Q3 is turned off and disconnects the load from the switch. This procedure energizes other switches connected to the same load, allow-



As shown in the schematic, a P-channel MOSFET (Q1) isolates the input signal voltage from the output without introducing an objectional level of offset voltage. An N-channel junction FET (Q2) provides a rapid turnoff capability because of its low "on" resistance. In order to prevent a short circuit, (Q3) is used to switch simultaneously with Q1, thus isolating the output from the shunt element. This leaves the output voltage at the cutoff level.

The switching voltage waveform is delayed for a few nanoseconds before it is applied to the gate of Q3, allowing the voltage charge on the

ing measurements to be made of signals from other sources in rapid succession.

Zener diodes D1 and D2 are connected to each input line to protect the switches from over-voltage due to surges, noise spikes, or excessive power inputs.

Source: R. L. Magee and L. E. Trowbridge of General Electric Co. under contract to NASA Headquarters (HQN-10488)

*Circle 7 on Reader Service Card.*

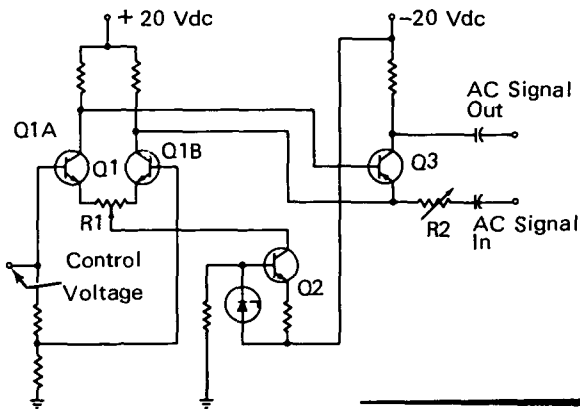
### SOLID-STATE CIRCUIT SWITCHES AC LOADS

This solid-state circuit is designed to switch ac signals which have peak amplitudes greater than 5 volts.

Applying a dc control voltage of 0.1 to 5.0 volts to the base of Q1A, causes it to conduct more heavily than section Q1B. Thus, the

collector of section 1 will be at a lower voltage than the collector of section 2, and Q3 will conduct to pass the ac signal. Output of this switch is flat within 3 db from 6 Hz to 21.5 kHz, with the use of 1 mfd coupling capacitors.

The circuit consists of a dual NPN transistor,



Q1, a current source, Q2, and an ac switch, Q3. Resistors R1 and R2 are initially adjusted to obtain proper switching action and to control the ac gain of the switch. With no dc control voltage applied, the collectors of Q1 are essentially at the supply potential of 20 Vdc; Q3 is non-conducting (its impedance is extremely high) and as a result, there is no ac signal output.

Source: C. P. Chapman and D. R. Rupnik (JPL-798)

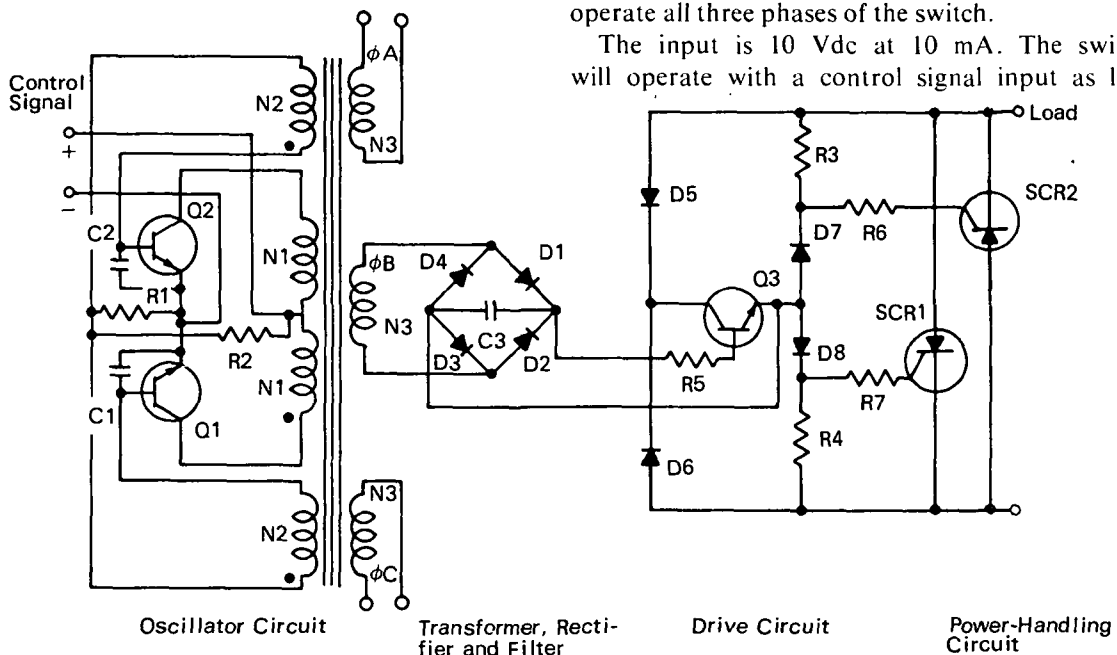
Circle 8 on Reader Service Card.

### SEMICONDUCTOR AC STATIC POWER SWITCH

The desirable characteristics of this static power switch include the absence of moving parts (and associated wear), and the high gain between the control power and the power transferred.

signal may or may not be grounded, an oscillator-transformer-rectifier circuit provides isolation between the control signal and the switch, and permits the use of a single control signal to operate all three phases of the switch.

The input is 10 Vdc at 10 mA. The switch will operate with a control signal input as low



The static switch is particularly suited in such applications as on-off regulation, position controls for the orientation of solar panels, radio antennas, and flashing lights.

Minimum power drain from the control signal is achieved by having the control signal turn on a small switch that supplies turn-on power to the main SCR's. Since the control

as 25 mW, over an operating temperature range of 233 to 353 K. The oscillator transformer has three output windings, each feeding a full-wave bridge rectifier and filter. The rectified output voltage is applied to the drive transistor (Q3) which saturates and supplies power to the SCR's (through D5 to D6, D7 to D8, and R6 to R7). The switch will turn on, over its operating

temperature range, when the line voltage is at least 8 volts. Under normal conditions, the drive transistor dissipates less than 0.1 watt. The switch has a design rating of 4 amperes and has a continuous overload capability of 14 amperes for a range of heat-sink temperatures

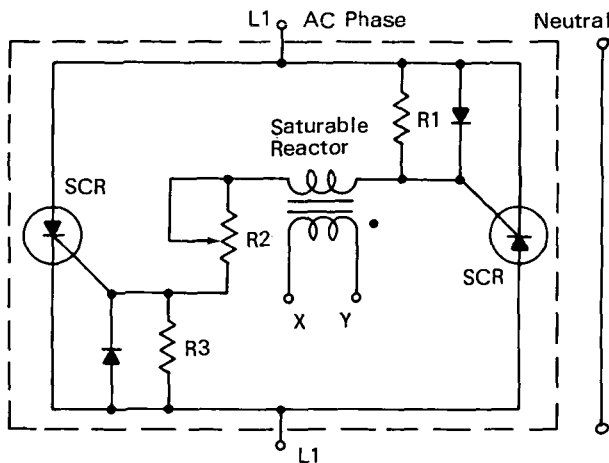
from 233 to 353 K. The noted voltage is 600 peak or 400 rms.

Source: James Vrancik of  
Lewis Research Center  
(LEW-10344)

*Circle 9 on Reader Service Card.*

### SOLID-STATE SWITCH CONTROLS AC POWER

Important features of the solid-state ac power switch shown in the figure include: (1) no moving parts; (2) explosion proof (no arcing); (3) fast switching times; and (4) longer operational life.



The switching action is initiated with the application of an external signal to the terminals, X and Y, of the saturable reactor, or (2) by merely shorting them together. This produces a condition of saturation, i.e., the secondary

winding is in a low impedance state which permits the SCR gate circuit to be completed. Depending on the ac polarity at the instant of saturation, the appropriate SCR fires and begins to conduct for the duration of that particular half cycle, while the other SCR remains turned off. At the end of the initial half cycle, the conducting SCR turns off because of the current reversal and the other SCR conducts for the remaining half of the cycle. The gate voltage for each SCR is developed across the voltage dividing network (composed of R1, R2, and R3) and the saturable reactor at the instant that the SCRs are not conducting. The circuit can be commutated at frequencies ranging from 60 to 1600 Hz. Modifications of this circuit can be used in 3- $\phi$  power control and in motor reversing applications.

Source: G. P. Paul of  
North American Rockwell Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-16092)

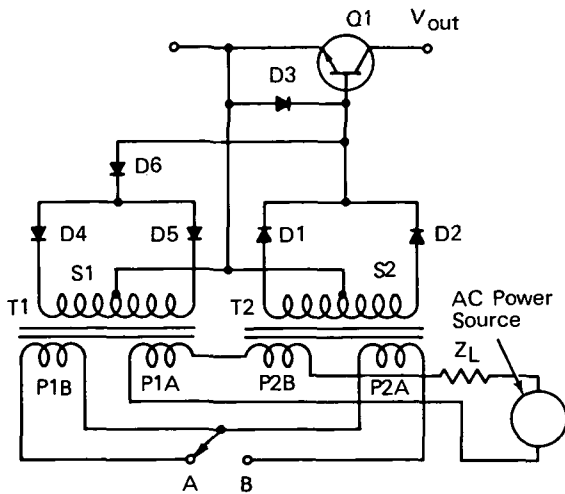
*No further documentation is available.*

### MAGNETICALLY COUPLED POWER SWITCH FOR POWER CONDITIONING EQUIPMENT

The transistor power switch shown in the figure isolates the ac power from the control circuitry. The switch has high efficiency and can accept a wide range of input voltages. Immediate applications include its use in voltage regulators and power conditioning equipment.

With the manual switch in the A position as shown, transformer T1 is short circuited and presents an extremely low impedance at the terminals of windings P1A. The ac source voltage,

minus the voltage drop across  $Z_L$ , appears across winding P2A of T2. This causes a forward base-drive voltage to appear from the base to emitter of Q1 and drive current is supplied through D1, D2, and windings S2 and T2. The drive voltage,  $V_{BE}$ , is sufficiently low so that the current shunted by the combination of D4, D5, D6, and winding S1 of T1 is insignificant.



With the switch in the B position, T2 is shorted and the ac source voltage appears across P1A of T1; this causes D3 to be forward biased, thereby holding Q1 off and "opening" the switch.

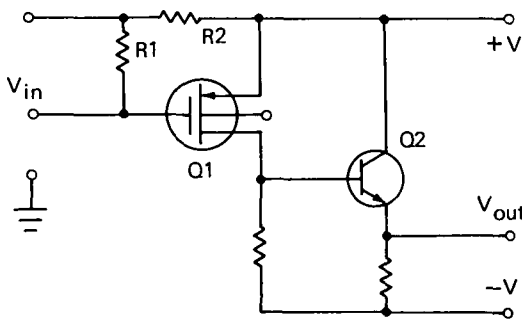
Slight modifications to the circuit and the addition of a saturable reactor would increase the higher power efficiency where variable loads are to be switched.

Source: A. S. Cherdak of  
Radio Corp. of America  
under contract to  
Goddard Space Flight Center  
(GSC-10023)

Circle 10 on Reader Service Card.

### SOLID-STATE SWITCH PROVIDES 20-MEGOHM ISOLATION

The unique feature of this isolation switch is the use of the ultrahigh input impedance MOS transistor Q1 to achieve ground isolation. Q1 is selected for low gate-source threshold voltage in order to interface with the logic input levels. Isolation between the input and output power supplies is greater than 20 MΩ;



rise and fall times of output pulses are less than 2μ sec; and the circuit is compatible with the output levels of standard integrated circuit logic modules.

R2 is the only connection between internal and external power. The input drive developed across R1, which enhances the conduction channel of Q1, provides the drive to Q2 and to the load. Zero voltage across R1 turns Q1 off and the output drops to the return voltage.

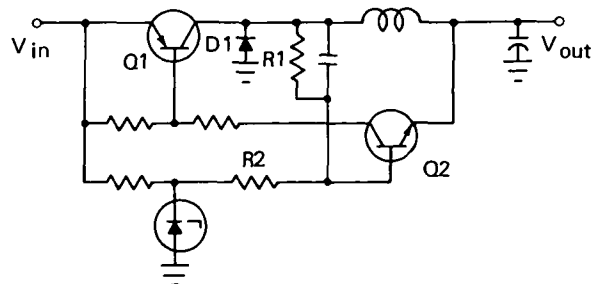
Source: C. L. Moberly of  
Motorola, Inc.  
under contract to  
Manned Spacecraft Center  
(MSC-11006)

Circle 11 on Reader Service Card.

### HIGH-EFFICIENCY SWITCHING REGULATOR

Switching regulators offer greatly improved efficiency compared to simple series or shunt regulators, but normally have very complicated circuits. This unit requires only 12 components and has a regulation efficiency of greater than 85%.

The regulator shown in the block diagram operates in either the "on" or "off" mode. When



a signal input  $V_{in}$  is applied to one side of the series inductor, the current begins to build up to a predetermined level. The switch is then turned off and the current flows through the flyback diode, D1.

The voltage comparator Q2 must have hysteresis to sustain oscillation, or else the series switch will operate in a linear mode. The opera-

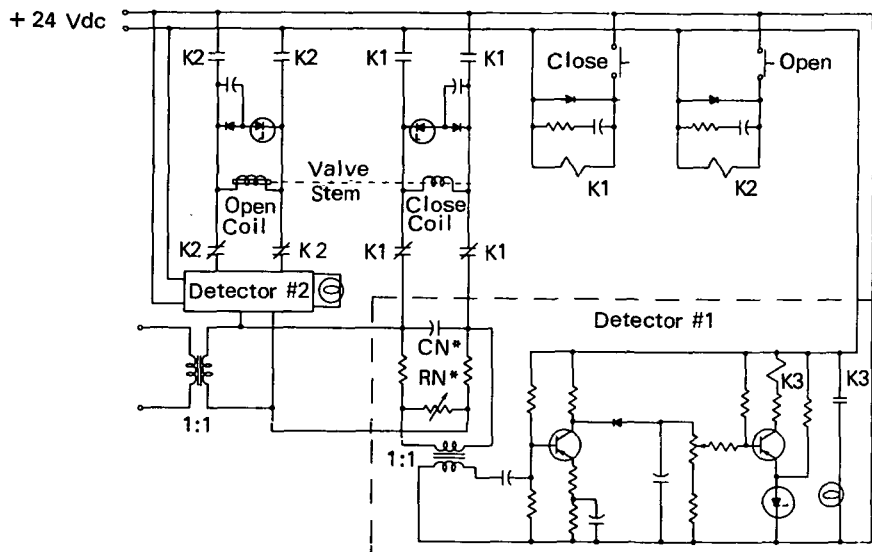
tion of Q1 and Q2 is similar to a Schmitt trigger, with R1 and R2 introducing the necessary hysteresis.

Source: A. G. Birchenough  
Lewis Research Center  
(LEW-11005)

*No further documentation is available.*

## Section 3. Solenoid Valve Control Circuits

### ELECTRONIC POSITION INDICATOR FOR LATCHING SOLENOID VALVES



The circuit shown in the figure can determine whether a double latching solenoid valve is opened, closed, or at some in-between position.

The change in impedance of the solenoid valve coil, caused by the change in position of the solenoid plunger with respect to the coil, unbalances a bridge network and thus provides a signal for the level detection circuitry. Identical detection circuits are connected to the valve coils so that if the valve is not fully opened or fully closed, neither detection lamp will be on.

Transient suppression is provided to eliminate damaging voltage spikes. No modification of the valve is required since the detector is con-

nected directly to the valve coil. The following documentation may be obtained from:

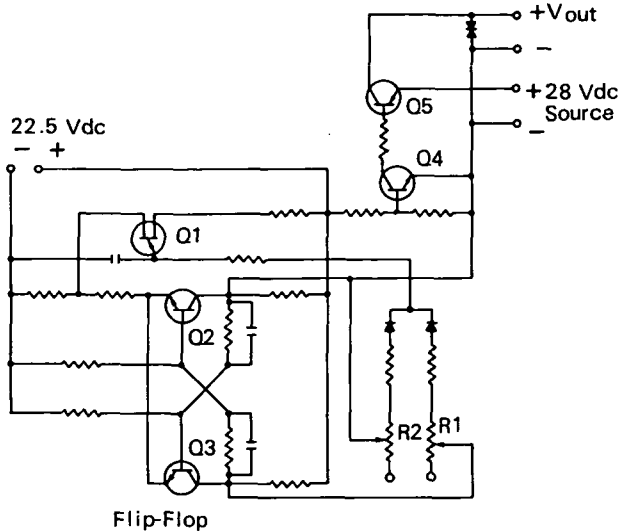
National Technical Information Service  
Springfield, Virginia 22151  
Single document price \$3.00  
(or microfiche \$0.95)

Reference:

NASA-TM-X-1760 (N69-20874), Electronic Position Indicator for Latching Solenoid Valves

Source: R. J. Frye, H. L. Wimmer, and  
R. Fischer  
Lewis Research Center  
(LEW-10926)

### VARIABLE-PULSE SWITCHING CIRCUIT ACCURATELY CONTROLS SOLENOID VALVE ACTUATION



The solid state switching circuit shown in the figure generates variable square wave pulses of sufficient power to operate a 28 V dc solenoid valve at precise time intervals.

The circuit includes a pulse-forming branch (Q1, Q2, and Q3) and an amplifier which powers the operation of the solenoid valve. Pulse width (on time) can be varied over a range of 10 to 40 msec by adjusting potentiometer R1. Similarly, the interval between pulses (off time) can be varied over a range of 8 to 350 msec by means of R2.

This type of circuit has been used to control a solenoid valve for precise time intervals of fluid flow in combustion experiments. With an addition of suitable relays, the circuit can be used for sequencing multiple flows in various processes.

Source: J. D. Gillett, of  
North American Rockwell Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-1895)

Circle 12 on Reader Service Card.

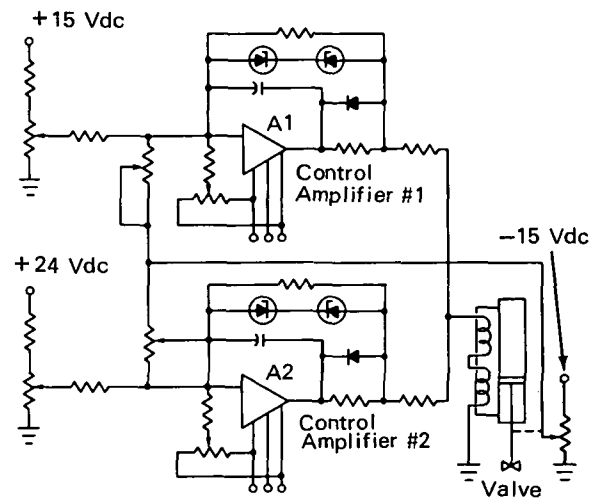
### REDUNDANT ELECTRONIC CIRCUIT PROVIDES FAIL-SAFE CONTROL

Closure of a valve is prevented and valve control is maintained to a close tolerance with this fail-safe control circuit. The controller can maintain the position of the valve (within 3% of the intended value) when the supply voltages are removed (or shorted) and when either output from the amplifiers is shorted.

The circuit is designed to enable the output of one amplifier to override a failure in the other amplifier. Additional reliability is achieved with separate power supplies for each amplifier.

The circuit shown in the figure operates in conjunction with a valve that opens upon loss of a signal, thus preventing the valve from closing when the control system fails.

The valve position error caused by a failure is inversely proportional to the gain of the two control amplifiers. Therefore, if the valve gain is low, the gain of the control amplifiers is increased to reduce the error. Conversely, a failed-closed valve system can be made by reversing the excitation voltage connections to the valve-position potentiometers.



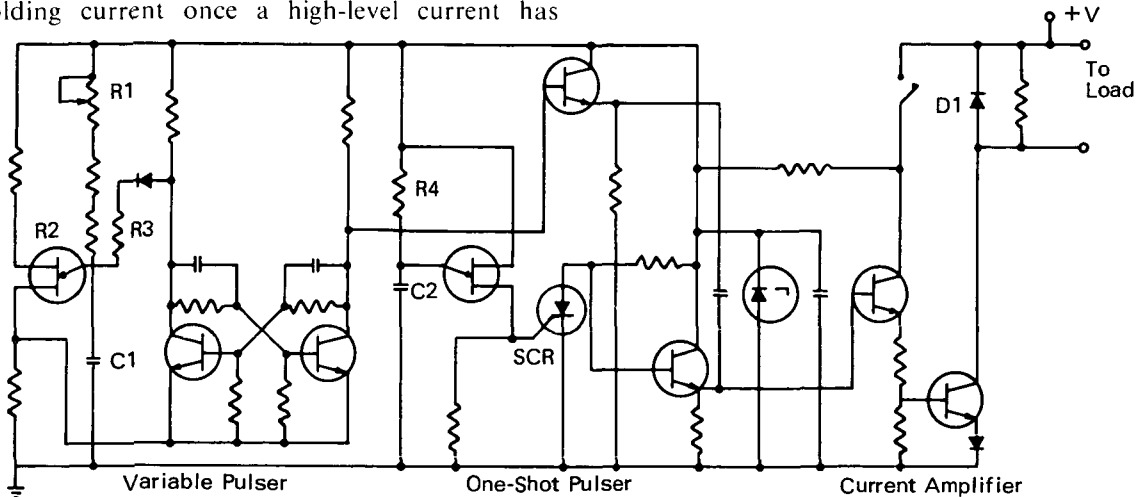
Source: J. W. Archer of  
Aerojet-General Corp.  
under contract to  
AEC-NASA Space Nuclear Systems Office  
(NUC-10389)

Circle 13 on Reader Service Card.

### SOLENOID VALVE DRIVER CIRCUIT

A variable duty-cycle pulser has an exceptionally high power efficiency when operating solenoid valves. The circuit provides a low-level holding current once a high-level current has

an emitter follower, to a two-stage current amplifier. The "one shot" pulser consists of a unijunction oscillator which triggers a silicon-controlled



actuated the solenoid valves. Initial energizing current is provided by a "one shot" pulser that causes full power to flow to the solenoid valves for a length of time sufficient for maximum pull-in. To obtain the solenoid valve holding current, a variable duty cycle pulser turns the power switch on and off. By adjusting the pulse duration and frequency, any desired value of effective solenoid valve holding current can be set and maintained. Diode D1 suppresses the induced-voltage surge when the solenoid valves are deenergized, and circulates the decaying coil current back through the coil. This effectively increases the decay time constant, making it independent of other circuit parameters. Thus, the duty cycle is decreased, which further increases the efficiency of the circuit. The variable duty cycle pulser consists of a bistable multivibrator which is triggered by a unijunction relaxation oscillator. The output of the multivibrator is capacitively coupled, through

rectifier, which, in turn, operates a transistor switch. This switch saturates the two-stage current amplifier until the silicon-controlled rectifier conducts. The switch on the initial pulse is determined by the time constant,  $C2 \times R4$ . The power switch consists of the two-stage current amplifier.

The circuit has successfully operated two solenoid valves simultaneously with an efficiency of 77 percent. A minimum holding current of 0.3 A is necessary to keep the solenoid valves held in. The pulse duration is set to 0.53 msec, and time between pulses is set to 2.6 msec, which yields a holding current of 0.5A.

Source: R. J. Mankovitz of  
North American Rockwell Corp.  
under contract to  
Manned Spacecraft Center  
(MSC-254)

Circle 14 on Reader Service Card.

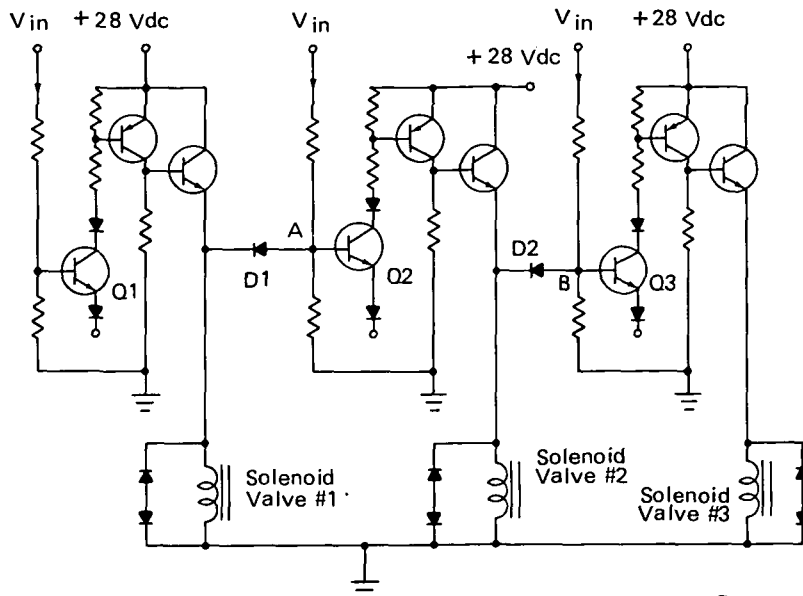
### FAIL-SAFE CIRCUIT CONTROLS SOLENOID VALVE OPERATIONS

Quite often, in process operations related to the petrochemical and pharmaceutical industries, control solenoid valves must operate in a specific sequence. Any deviation could result

in a catastrophic condition. The circuit shown in the figure prevents out-of-sequence or premature operation of control solenoid valves, during both opening and closing cycles.

Electronic switches (Q1, Q2, and Q3) coupled with interlocking diodes D1 and D2 are used to control the operation. The cycle begins with

valve is lost at any stage, all succeeding stages close in rapid succession to provide a fail-safe condition.



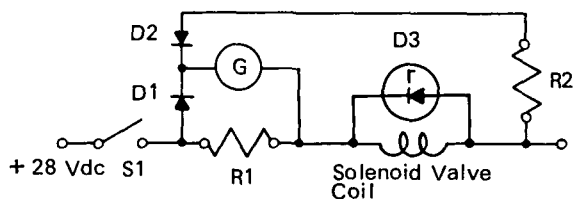
valve #1 opening before valve #2 and closing soon after #2 opens. Since the resistances of the valve coils are low (less than  $30\Omega$ ) the voltages at points A and B cannot rise sufficiently to turn on Q1, unless the preceding valve is energized. If the control signal to a

Source: O. B. Marshall of  
North American Rockwell Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-18162)

*No further documentation is available.*

### CIRCUIT MONITORS POPPET MOVEMENT OF SOLENOID VALVES

A large number of 28-Vdc solenoid valves can be simultaneously and remotely monitored for poppet movement for the purposes of



determining the operating times for opening and closing modes. A diode circuit shown in the figure monitors the current mode when the solenoid is energized (opening the valve) and monitors the voltage mode when the solenoid is deenergized (closing the valve). This circuit requires only one galvanometer for both modes of operation.

The circuit divides the current to the solenoid through R1, D1, and the galvanometer. D2 blocks the path through R2. On closing, the voltage across the solenoid reverses polarity as a result of the decreasing magnetic field of the solenoid, and the current path now divides through D2, R2, D2, and the galvanometer; D1 blocks the path through R1. R2 is selected to give the desired galvanometer deflection.

Source: G. E. Marriner of  
North American Rockwell Corp.  
under contract to  
Manned Spacecraft Center  
(MSC-11617)

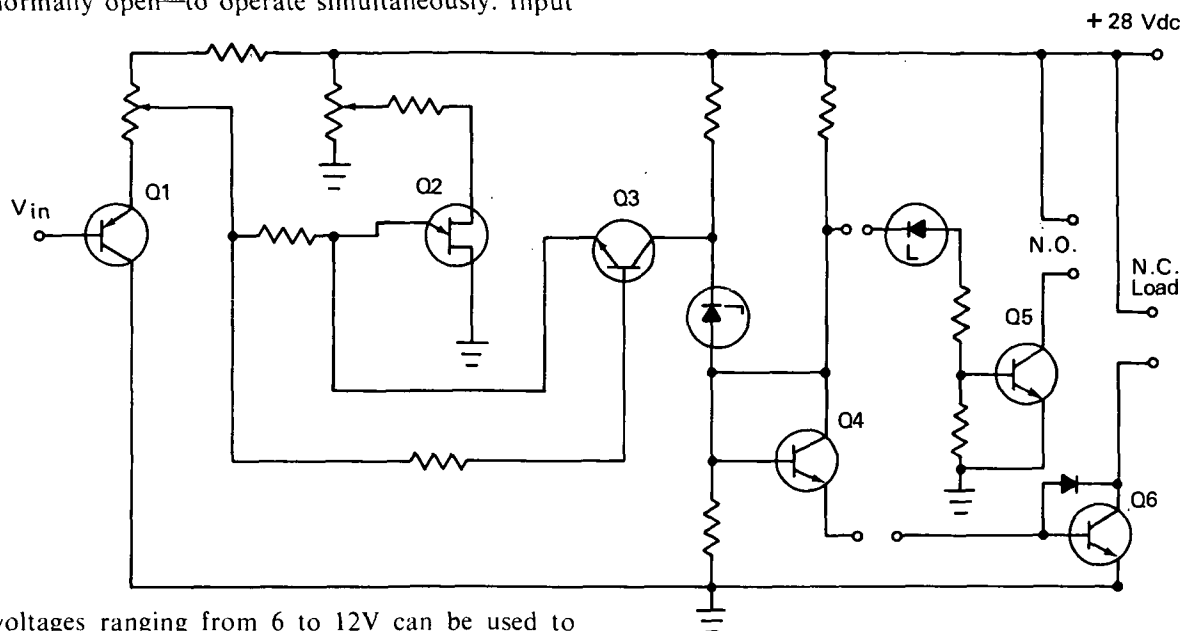
*No further documentation is available.*



### SWITCHING CIRCUIT WITH HYSTERESIS CHARACTERISTICS CONTROLS VALVE OPERATION

The hysteresis characteristic of the circuit shown in the figure allows two solid state switches—one normally closed and the other normally open—to operate simultaneously. Input

are closed; simultaneously, Q6 turns off and the N.C. contacts are opened. The opening and closing of the contacts in the switch outputs can



voltages ranging from 6 to 12V can be used to trigger the circuit. When the input voltage is below the triggering level, very little current flows in the emitter of Q2; the base and the emitter of Q3 are at the same potential, and Q3 is cut off. An input voltage exceeding the triggering threshold causes Q2 and Q3 to be saturated. The saturation of Q3 removes base current flow to Q4, thus turning it off. When Q4 is off, Q5 turns on and the N.O. contacts

be used to control the current flowing through the solenoid valve coils.

Source: R. E. Melton of  
SPACO, Inc.  
under contract to  
Marshall Space Flight Center  
(MFS-13363)

*No further documentation is available.*

### VALVE ACTUATOR CIRCUIT MINIMIZES OPERATING POWER REQUIREMENTS

The solenoid valve driver circuit reduces the input electrical power consumption during continuous operation to less than one-tenth that of conventional circuits. The simplicity of the circuit and the minimal power requirements make this type of valve control attractive in applications where battery power is available.

Circuit operation begins by closing the switch SW1 to enable a charging current to

flow through C1 and the solenoid coil (see fig. 1). As the current begins to increase, the Zener diode (D1) breaks down (at 60 mA) and causes Q1B to be turned off. The switch now becomes sensitive to a new current level (20 mA) determined by R2 and R3. When the current through the solenoid decays to approximately 20 mA, the switch then begins to cycle on and off in order to maintain this same current level

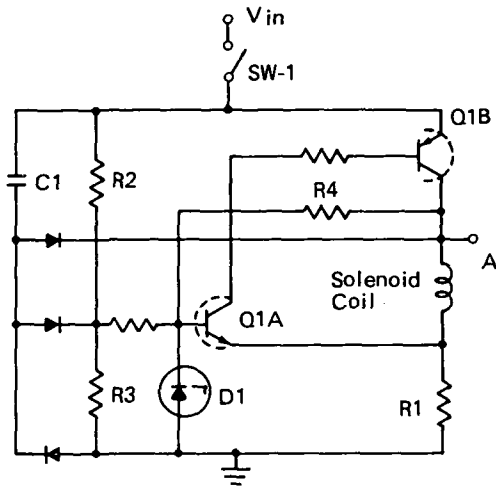


Figure 1.

through the solenoid. The cycling rate and current fluctuations are controlled by adjusting the value of the positive feedback resistor R4. Figures 2A and 2B demonstrate the periodic nature of the current-voltage properties and subsequent power savings of the central circuit.

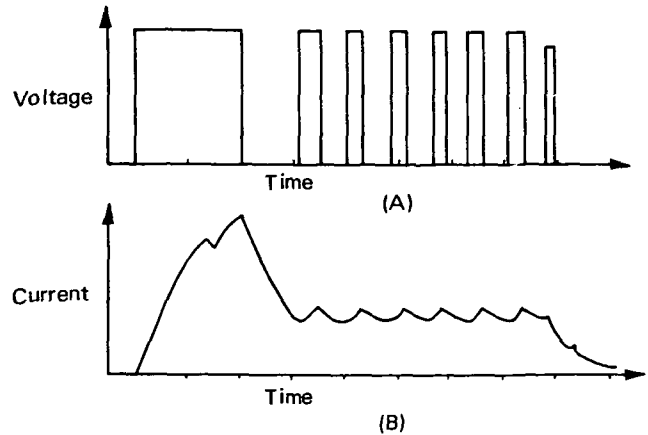


Figure 2.

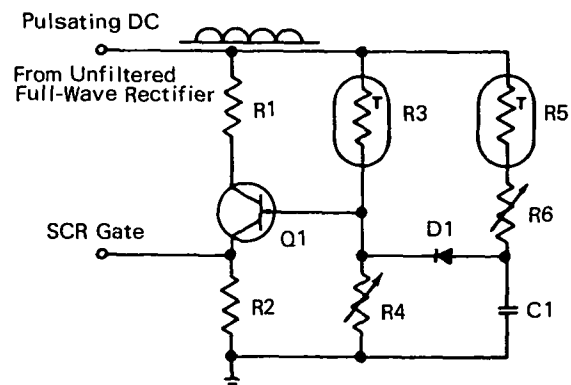
Source: W. E. Crawford of  
Caltech/JPL  
under contract to  
NASA Pasadena Office  
(NPO-10716)

Circle 15 on Reader Service Card.

## Section 4. General Purpose Control Circuits

### HEATER CONTROL CIRCUIT PROVIDES BOTH FAST AND PROPORTIONAL CONTROL

A conventional proportional control circuit, combined with a fast-heating circuit (R3 and R4), consisting of a voltage divider, provides a voltage at low temperatures which turns on transistor Q1 for each dc input pulse. With Q1 "on" the heater operates during the full input pulse duration. As the temperature rises above a preset value, the change in resistance of R3 (a thermistor) reduces the voltage supplied by the voltage divider so that heater control is shifted to the proportional control circuit. The SCR gate output from unijunction transistor Q1 is then delayed on each input dc pulse



by the charge time of capacitor C1. Because of this delay, the heater does not turn on in the early portion of each input pulse. Diode D1 is used to isolate the fast heating circuit from the proportional control circuit.

When provided with proper sensors, the circuit can be adapted to provide control of other parameters, such as pressure, volume, fluid

level, motor speed, voltage, and light intensity.

Source: R. W. Baslock of  
IBM

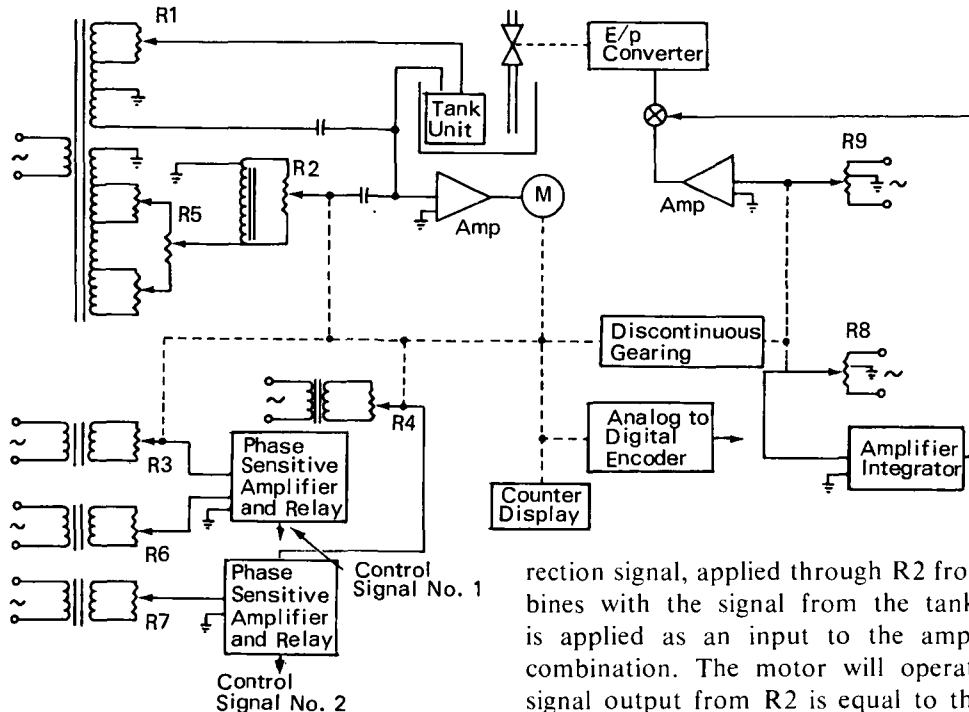
under contract to  
Marshall Space Flight Center  
(MFS-906)

*Circle 16 on Reader Service Card.*

## CONTROL SYSTEM MAINTAINS SELECTED LIQUID LEVEL

A single-sensor control system maintains liquid hydrogen at a desired level, regardless of boiloff of the hydrogen.

units. Potentiometer R5 is adjusted to select the desired tank fill level, which may range from 60 to 100 percent of the tank capacity. A cor-



This gaging system would have application in controlling liquid levels in tank cars where the fluids frequently boil or leak away, or for use in industrial processes where the level of fluids must be held constant.

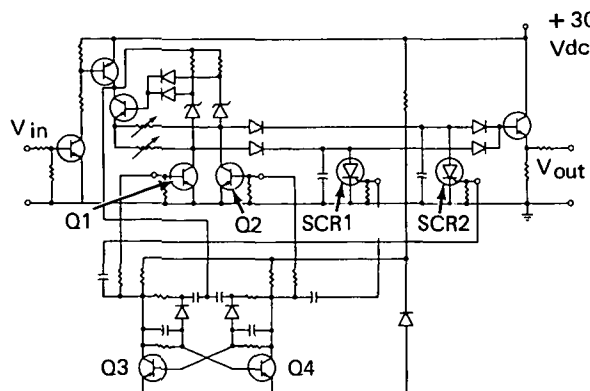
Initially, a calibration signal is obtained from empty-adjustment potentiometer R1 and applied through the tank unit (liquid level sensor) to an amplifier-motor combination. Mechanical linkage from the motor extends to the counter display, an analog-to-digital encoder, and gearing

rection signal, applied through R2 from R5, combines with the signal from the tank unit, and is applied as an input to the amplifier-motor combination. The motor will operate until the signal output from R2 is equal to the tank unit signal; this indicates that the fuel level in the tank has reached 100 percent of the setting of R5. The counter display unit gives a visual percentage output indicative of the wiper position of R2. The analog-to-digital encoder (an optional circuit item) accepts the analog signal provided by the gearing and provides a digital output for computer use. Potentiometers R3 and R4, in conjunction with R6 and R7, respectively, may be set to desired levels to generate control signals from phase-sensitive amplifier and relay circuits.

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C. 2457 (f)] to Honeywell, Inc., 2600 Ridgeway Rd., Minneapolis, Minnesota 55413.

Source: L. Bergeson and J. W. Schuck of Honeywell, Inc. under contract to Marshall Space Flight Center (MFS-470)

### SOLID-STATE SWITCHING USED TO SPEED UP CAPACITIVE INTEGRATOR



This variable pulse width circuit eliminates conventional relays which have limited operating lifetime, draw appreciable power, and cannot be switched in less than a few msec. The circuit has application in a process control system that uses a variation in pulse width to indicate parameter changes in the process function.

Referring to the schematic, the circuit employs capacitor integrators to convert the

signal input pulses to an analog voltage proportional to the pulse width. Transistors Q1 and Q2 are used to steer each input pulse to the proper capacitor in a sequence of charge, discharge, and read. SCR1 and SCR2 are alternately pulsed "on" by the bistable multivibrator composed of Q3 and Q4 to discharge the capacitor used in the previous cycle. The resultant output voltage is linearly proportional to the input pulse width. Important circuit design parameters include: (1) the ability to integrate either high or low duty cycle pulses, with repetition rates ranging from 1 to 10,000 pulses per sec, with negligible ripple factors; and (2) a high input impedance (500 K $\Omega$ ) while maintaining a relatively low output impedance.

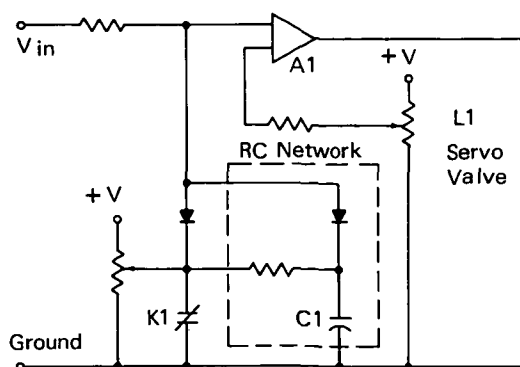
Source: A. L. Newcomb, Jr.  
Langley Research Center  
(LAR-104)

Circle 17 on Reader Service Card.

### PRESSURE TRANSIENTS REDUCED DURING STARTUP OF HYDRAULIC PUMP

The addition of an RC network to a pump control circuit reduces the pressure transients in a hydraulic system when the pump is started. The RC network electrically retards the pump hanger movement of the servo-controlled, variable displacement pump and prevents damage to system components caused by the pressure transients.

A simplified electrical schematic of the pump hanger control circuit is shown in the figure. In order to start the pump motor, relay contact K1 is closed, thus grounding the input control



signal. Grounding the input signal causes a zero output from the differential amplifier, and therefore a minimum output position of the pump hanger. After the motor is started, K1 opens and the increased current flow into A1 generates a voltage output to the pump hanger-positioning servo valve. The pump hanger is then driven towards the maximum output position by the servo valve. An exponential movement of the hanger is achieved as a result of the current-charging characteristics of C1. The effects of the network to the hanger response, during operation after startup, are eliminated by

maintaining the voltage on C1 and the proper level.

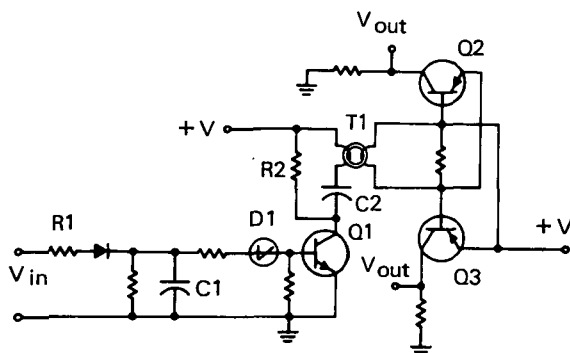
The pump hanger response can be varied from 250 msec to 5.0 sec by changing the value of C1. Actual performance tests indicate a reduction in pressure transients by a factor of 3.

Source: W. L. Flowerday of  
The Boeing Co.  
under contract to  
Marshall Space Flight Center  
(MFS-15141)

*No further documentation is available.*

### SOLID-STATE RELAY ELIMINATES RF NOISE

This solid state circuit replaces an equivalent electromechanical relay. Power dissipation in the "off" (deenergized) mode is less than 1 mW



and isolation is provided between control and switching functions. The circuit has the same input rf interference noise immunity as a relay, and since mechanical contacts are eliminated the lifetime is increased.

In operation, the applied input signal charges C1 sufficiently to cause D1 to conduct; Q1

turns on, and C2 couples the signal to pulse transformer T1 which develops a secondary voltage pulse. The use of C2 in series with T1 provides a relatively high initial current for a short period of time, since C2 begins to charge; the current is then reduced to a low level (limited by R2) when C2 is fully charged. When the input signal is removed, Q1 turns off and C2 now discharges through T1, causing a secondary voltage pulse of the opposite polarity. Thus, a secondary pulse in one direction represents a relay energized condition, while an opposite pulse represents a relay deenergized condition.

Source: J. R. Owen of  
IBM Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-13547)

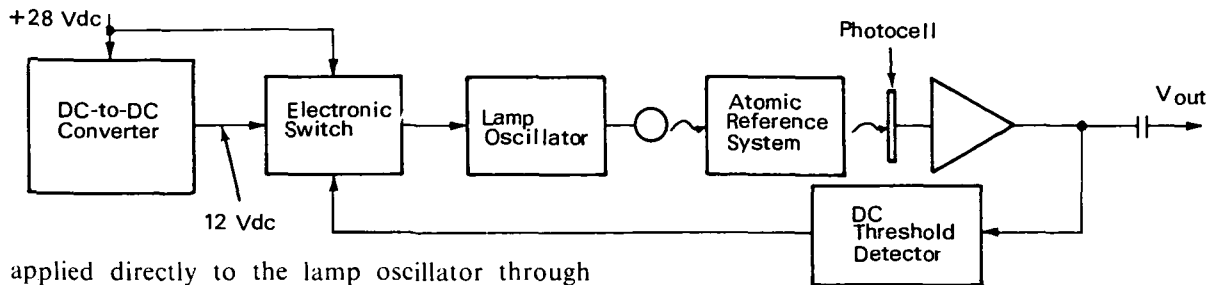
*No further documentation is available.*

### LAMP STARTING SWITCH FOR LOW POWER OPERATION

Alkali vapor lamps should be operated at the lowest possible power level, to increase the life of the lamp. However, the requirement for low operating power is in conflict with the requirement for initially striking the lamp since high power and high voltage are required for the ignition.

The circuit shown in the figure ignites the lamp and then transfers the lamp to a low-power continuous-operation mode. An electronic switch controlled by the output from a photocell transfers a high voltage-to-low voltage supply after the lamp has been ignited.

The 28 Vdc input starting power can be

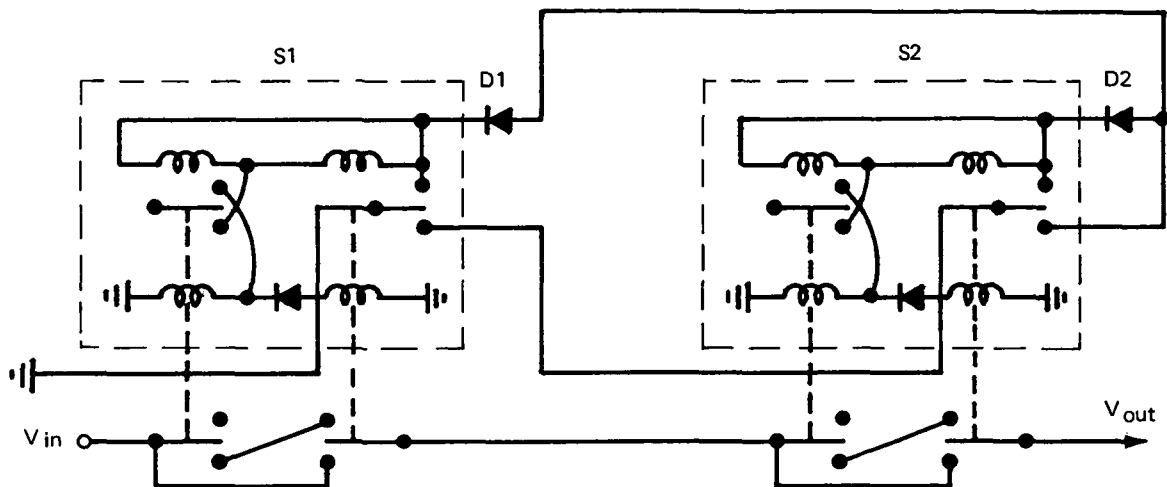


applied directly to the lamp oscillator through the switch. When the lamp ignites, current is generated in the photocell and is sensed by the dc threshold detector, which activates the electronic switch. A 12-Vdc supply is then applied to the lamp oscillator for continuous running operation. This switching action minimizes the total power required to sustain the lamp in its proper discharge mode.

Source: A. Helgesson of  
Varian Associates  
under contract to  
Manned Spacecraft Center  
(MSC-11664)

*No further documentation is available.*

### AN ULTRARELIABLE SWITCH



This circuit (called a cell) switches in the same manner as a relay and is capable of detecting most failures within itself. Coupling several cells together permits automatic replacement of a failed cell with a spare, and thereby significantly increases the probability of successful operation. The circuit consumes a minimal amount of power by eliminating power to the spare cells.

Each cell includes two 2-position latching relays of the double-pole double-throw type, and two steering diodes. One cell (S1) per-

forms the switching functions until it fails, and is then replaced by another cell (S2). Besides functional redundancy, component redundancy is used within a cell to increase the probability of automatic cell replacement after a component failure. The relays are double-coil types which are capable of switching without developing chatter.

Source: J. R. Kinkel  
(JPL-90831)

*Circle 18 on Reader Service Card.*

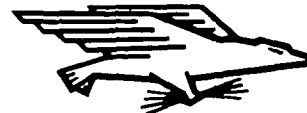
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